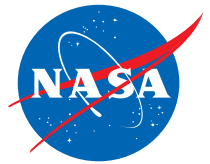


NASA-DoD Lead-Free Electronics Project

NASA Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM) Website

July 6, 2009

Overview

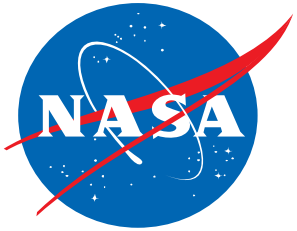
- Testing project will build on the results from the JCAA/JGPP LFS Project
- The primary technical objective of this project is to undertake comprehensive testing to generate information on failure modes/criteria to better understand the reliability of:
- Packages (e.g., Thin Small Outline Package [TSOP], Ball Grid Array [BGA], Plastic Dual In-line Package [PDIP]) assembled and reworked with lead-free alloys
- Packages (e.g., TSOP, BGA, PDIP) assembled and reworked with mixed (lead/lead-free) alloys.
- Project documents, test plans, test reports and other associated information will be available on the web:
- NASA-DoD Lead-Free Electronics Project: http://www.teerm.nasa.gov/projects/NASA_DODLeadFreeElectronics_Proj2.html
- JCAA/JGPP Lead-Free Solder Project http://www.teerm.nasa.gov/projects/LeadFreeSolderTestingForHighReliability_Proj1.html

Comparison of NASA-DoD LFE Project to predecessor JCAA/JG-PP LFS Project

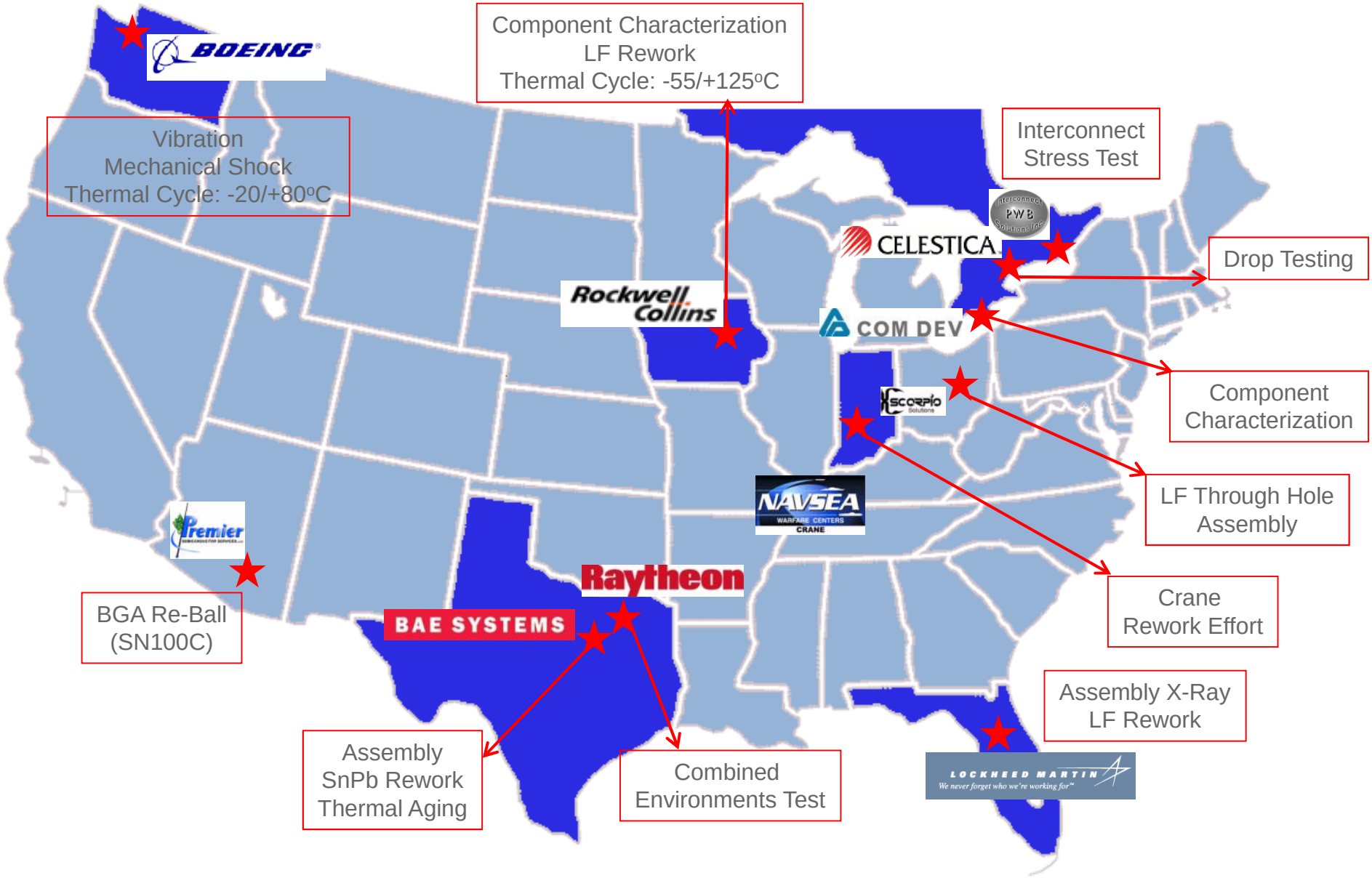
- **Similarities**
- Virtually identical test vehicle
- Procedures identical for most tests
- Same facility for assembly
- SN100C being used for wave soldering

- **Differences**
- Test articles will be thermally aged after assembly (100^{o}C for 24 hours)
- Increased rework
- Increased solder mixing
- Mechanical shock test procedure
- Drop testing
- Immersion Ag surface finish for most test vehicles (Limited number will have ENIG)
- SAC305 being used for reflow soldering
- SN100C being used for reflow soldering

Project Stakeholders



NASA-DoD Lead-Free Electronics Project Stakeholders by Location

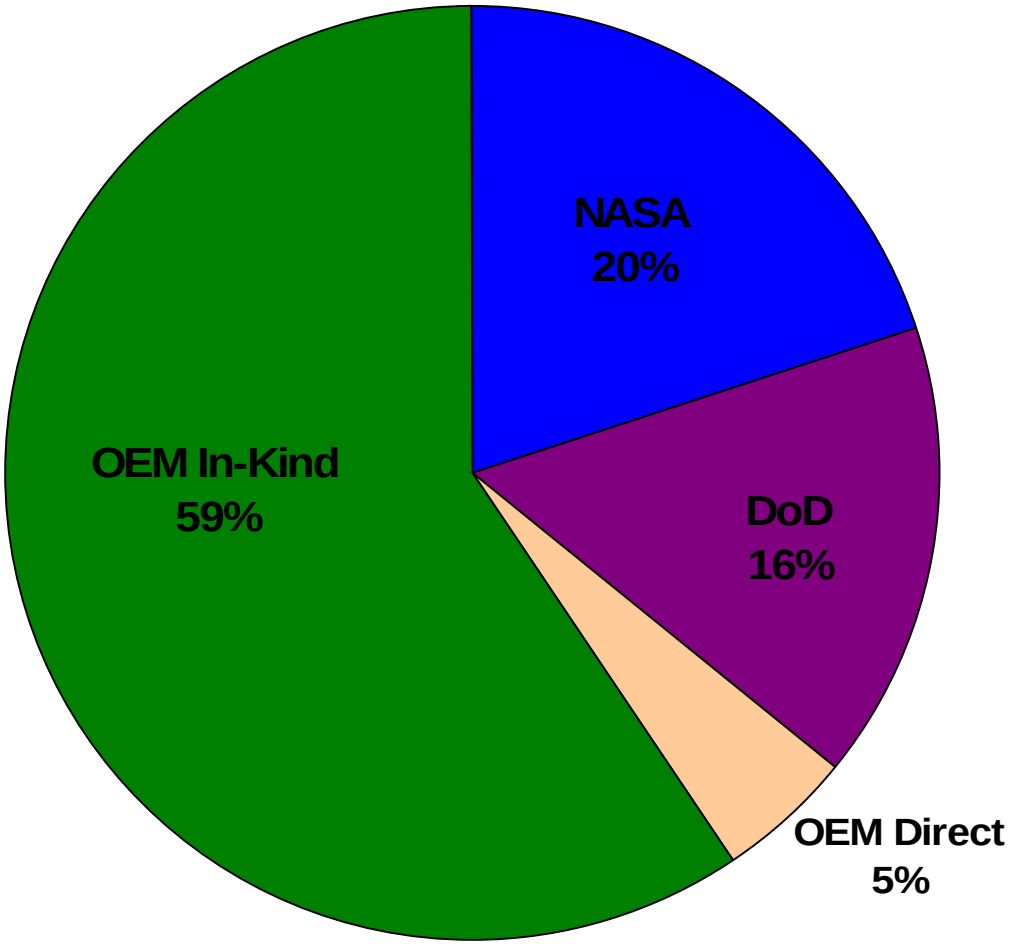


Joint Test Protocol Endorsement

- Endorsement signifies agreement that the JTP contains performance and technical requirements applicable to specific applications within programs, and provides the consensus needed to move forward with testing.

- AIA (Aerospace Industries Association)
- Air Force - Electronic Engineer (WR-ALC/ENFM)
- Air Force - Director of Engineering (DOE) for the 312/326 Aeronautical Systems Wing (AESW); Wright-Patterson Air Force Base
- Army Research Lab
- Headquarters - Air Force Space Command
- NASA - NEPP Program
- NASA-MSFC - Packaging, EEE Parts & Electrical Manufacturing Branch Chief
- Naval Air Warfare Center, Aircraft Division
- MDA – PMP Program Lead
- NSWC Crane Division - 2M Project Manager
- NSWC Crane Division - 2M (Miniature/Microminiature) Electronics Technician
- NSWC Crane Division - Electronics Engineer, Testing: Printed Circuit Technologies Branch
- NSWC Crane Division - Materials Engineer; FA/MA Branch, Flight Systems Division
- BAE Systems - Principal Process Engineer
- BAE Systems - Vice President of Engineering for Electronics and Integrated Solutions
- Celestica - Director of Technology - IAD sector
- COM DEV - Director, Design Integrity
- General Dynamics - Design Assurance Engineering Manager
- Harris - Process Engineering Group Lead
- Lockheed Martin - Engineering Manager
- Nihon Superior - President of Nihon Superior
- Radiance Technologies, Inc. - AERI Program Manager
- Rockwell Collins - Director, Advanced Manufacturing Technology
- TT Apsco - Vice President and General Manager
- Willcor Inc. - Best Manufacturing Practices

Contributions to the NASA-DoD Lead-Free Electronics Project ~$2 Million



Lead-Free Solder Alloys

- Which ones?

- SAC305 (Sn3.0Ag0.5Cu)
  - Surface mount assembly

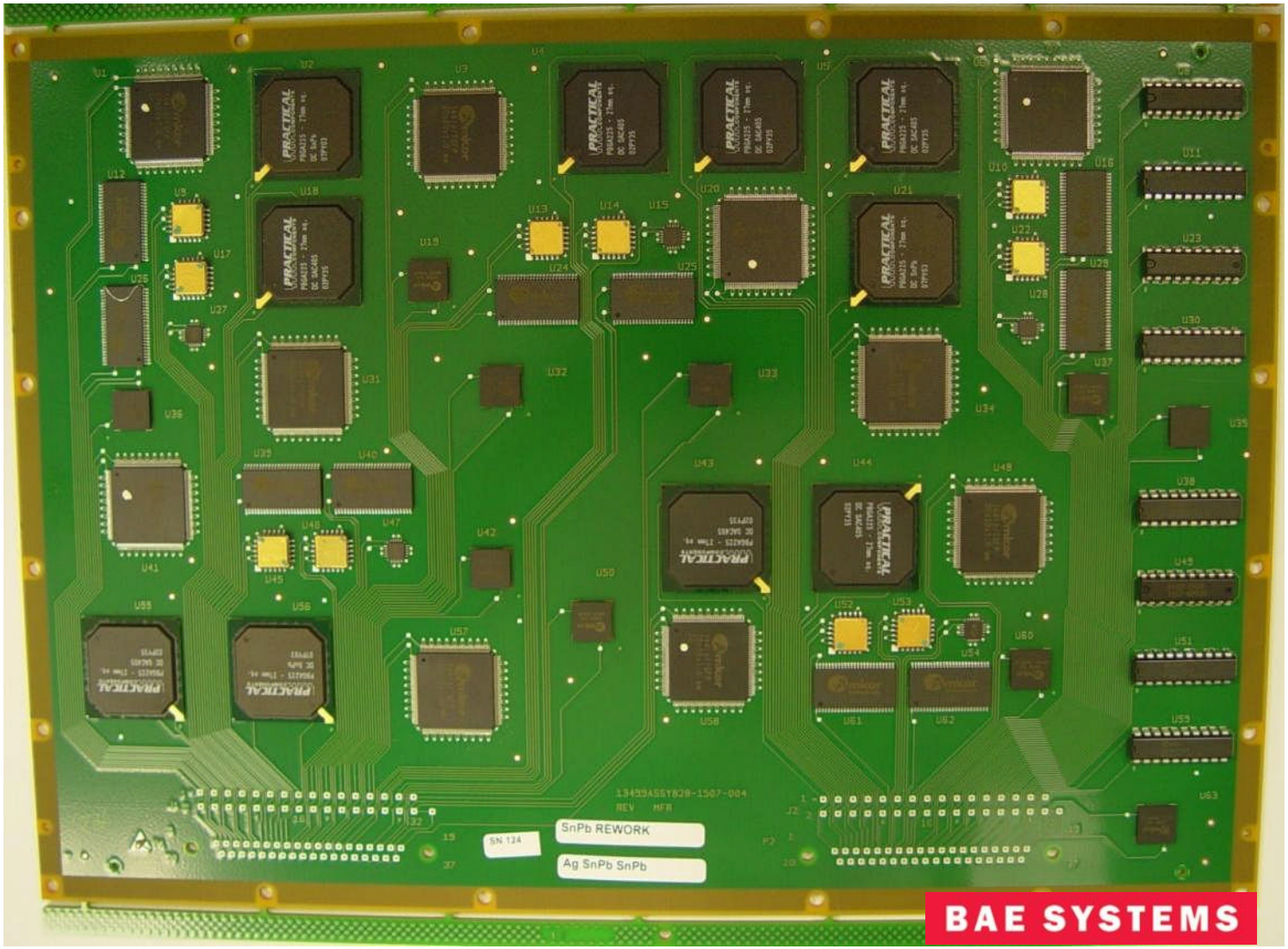
    This alloy was chosen for reflow soldering because this particular solder alloy has shown the most promise as a primary replacement for tin-lead solder. The team decided that they wanted to select at least one “general purpose” alloy to be evaluated and it was determined that the SnAgCu solder alloy would best serve this purpose.

- SN100C (Sn0.7Cu0.05Ni+Ge)
  - Plated through hole
  - Surface mount assembly

    This alloy is commercially available and the general trend in industry has been switching to the nickel stabilized tin-copper alloy over standard tin-copper due to superior performance. In addition, this nickel-stabilized alloy does not require special solder pots and has shown no joint failures in specimens with over 4 years of service.

Test Vehicles

- 193 Test Vehicles Assembled by BAE Systems (Irving, Texas)
  120 = “Manufactured”
  73 = “Rework”



Component Finish/Solder Combinations

SnPb Manufactured Test Vehicles				
Component	**Component Finish**	**Reflow Solder**	**Wave Solder**	**Board Finish**
BGA-225	SAC405	SnPb		Immersion Silver
BGA-225	SnPb	SnPb		
CLCC-20	SAC305	SnPb		
CLCC-20	SnPb	SnPb		
CSP-100	SAC105	SnPb		
CSP-100	SnPb	SnPb		
PDIP-20	NiPdAu		SnPb	
PDIP-20	Sn		SnPb	
QFN	Matte Sn	SnPb		
TQFP-144	Matte Sn	SnPb		
TQFP-144	SnPb Dip	SnPb		
TSOP-50	SnBi	SnPb		
TSOP-50	SnPb	SnPb		

Profiles used during assembly

Reflow Profile = SnPb
Preheat = ~ 120 seconds @140-183°C
Solder joint peak temperature = 225°C
Time above reflow = 60-90 sec
Ramp Rate = 2-3 °C/sec

Wave Profile = SnPb
Solder Pot Temperature = 250°C
Preheat Board T = 101°C
Peak Temperature = 144°C
Speed: 110 cm/min

Component Finish/Solder Combinations

Lead-Free Manufactured Test Vehicles							
Component	Component Finish	Set A			Set B		
		Reflow Solder	Wave Solder	Board Finish	Reflow Solder	Wave Solder	Board Finish
BGA-225	SnPb	SAC305		Immersion Silver ------- A limited Number of Boards will be Built with ENIG	SN100C		Immersion Silver
BGA-225	SAC405	SAC305			SN100C		
CLCC-20	SnPb	SAC305			SN100C		
CLCC-20	SAC305	SAC305			SN100C		
CSP-100	SnPb	SAC305			SN100C		
CSP-100	SAC105	SAC305			SN100C		
PDIP-20	NiPdAu		SN100C			SN100C	
PDIP-20	Sn		SN100C			SN100C	
QFN	Matte Sn	SAC305			SN100C		
TQFP-144	SnPb Dip	SAC305			SN100C		
TQFP-144	Matte Sn	SAC305			SN100C		
TSOP-50	SnPb	SAC305			SN100C		
TSOP-50	SnBi	SAC305			SN100C		

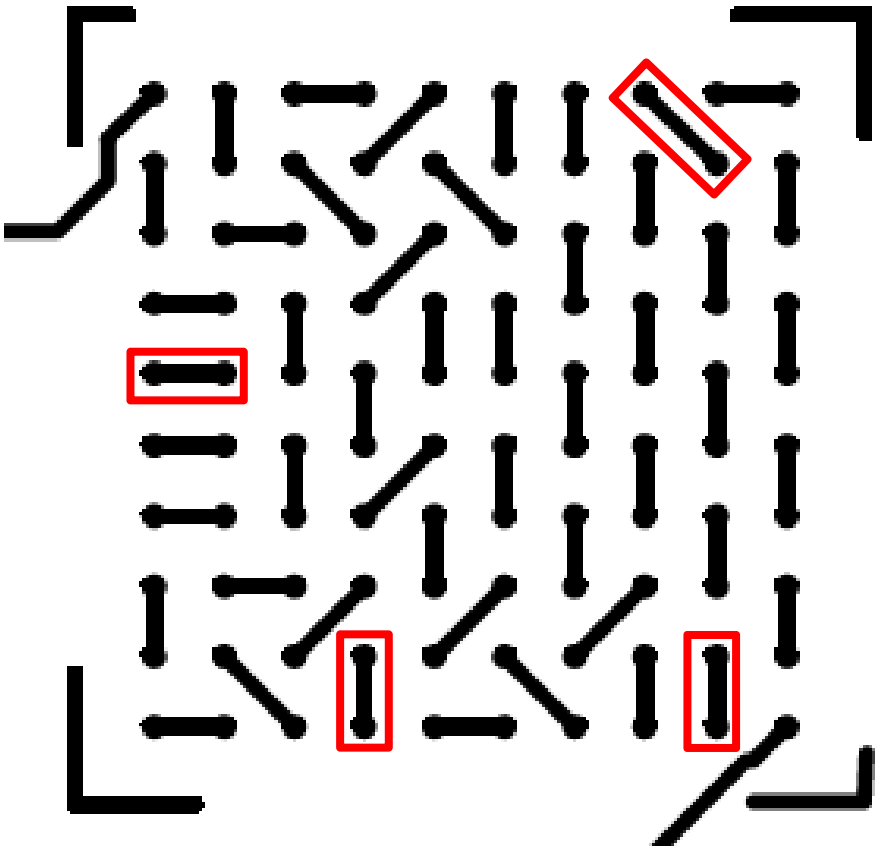
Profiles used during assembly

Reflow Profile = SAC305
Preheat = 60-120 seconds @150-190°C
Peak temperature target = 243°C
Reflow:~20 seconds above 230°C
~30-90 seconds above 220°C

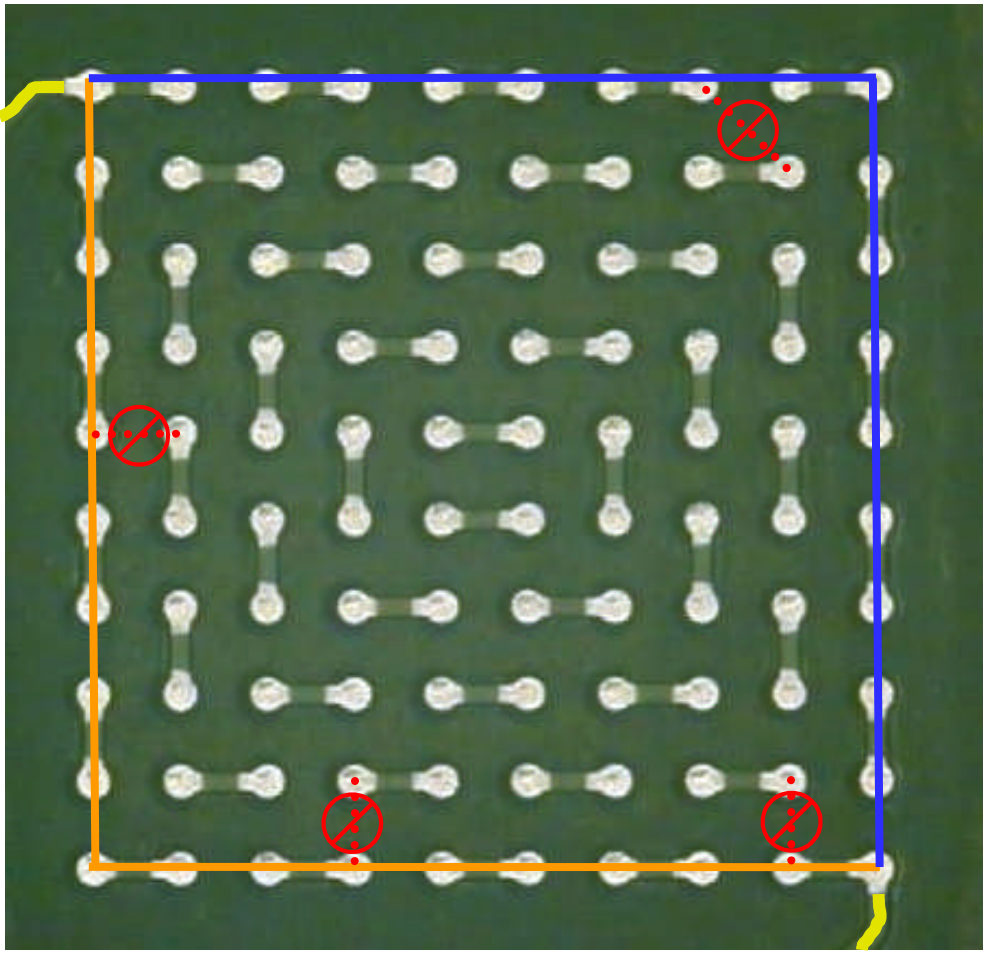
Wave Profile = SN100C
Solder Pot Temperature = 265°C
Preheat Board T = 134°C
Peak Temperature = 157°C
Speed: 90 cm/min

CSP Issue

- When reviewing the CSP data, please note that the CSP components on all test vehicles only have continuity in the outside solder balls.



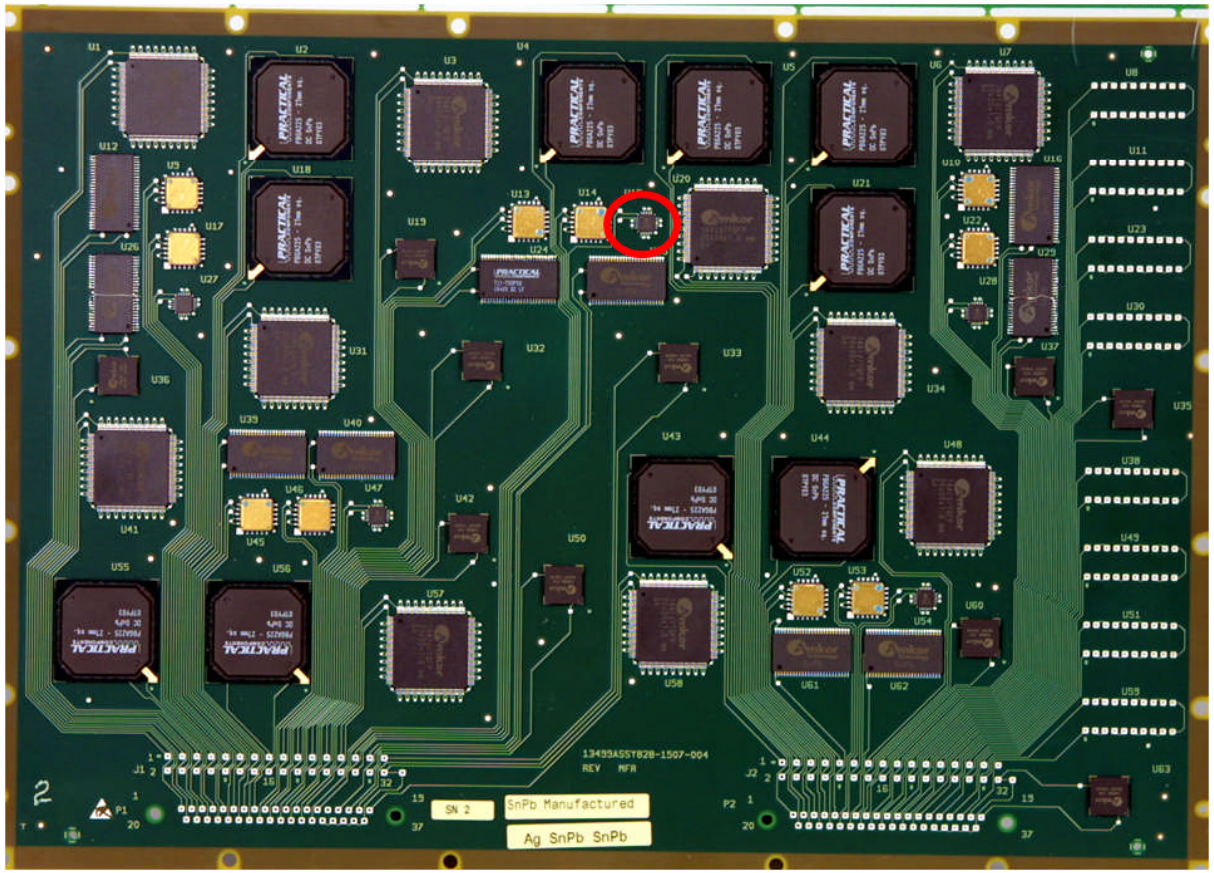
Links from the outside row of balls to the center rows do not exist on the test vehicles

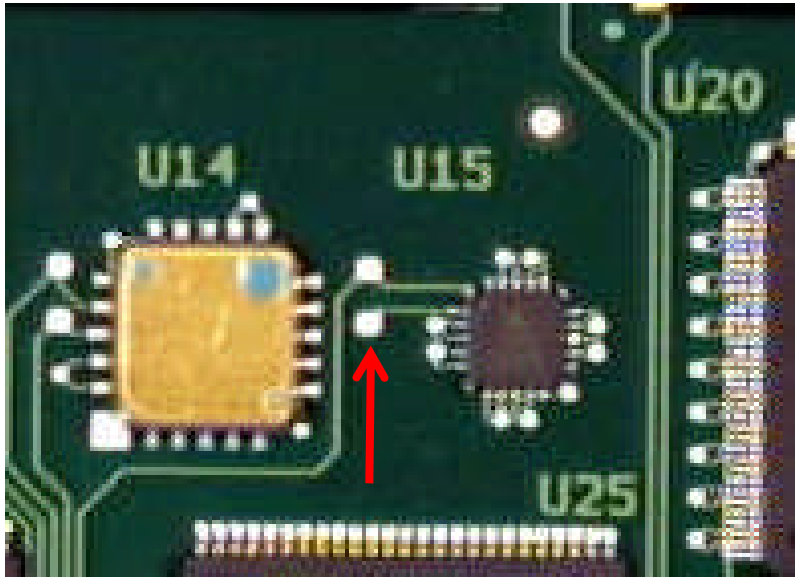


In order for a CSP component failure to be recorded, breaks in both sides of the continuity box must occur.

Component U15 = QFN

- Component U15, a QFN, is missing a wire trace. Test data cannot be collected for this component. Jumper wires were considered for thermal cycle testing but were not used. For vibration, drop, mechanical shock and combined environments testing, it was determined that a jumper wire is not feasible.

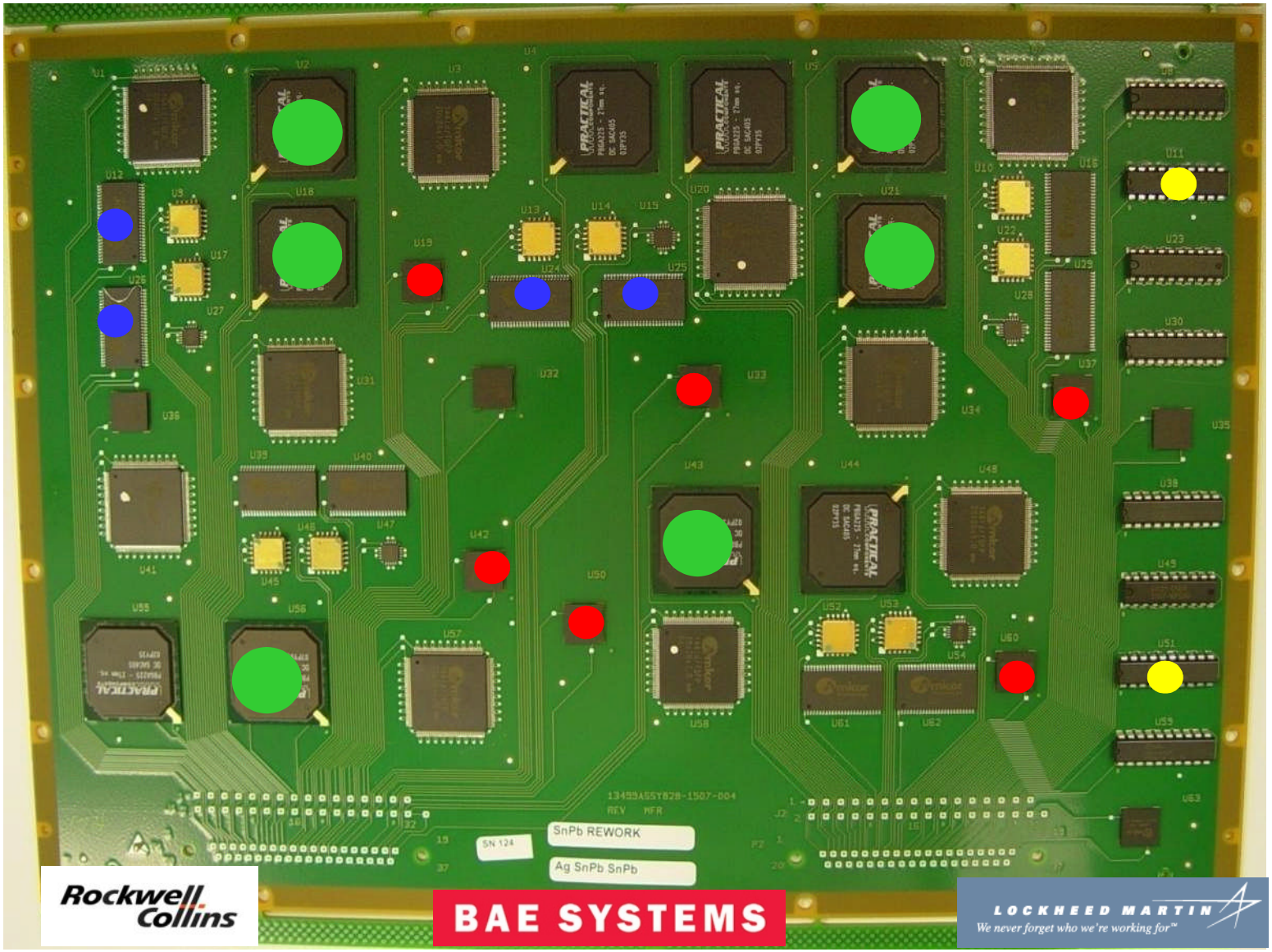




“Rework” Test Vehicles

- 73 Test vehicles being reworked (sub-set of the 193 assembled)
- 3 Locations completed the rework

RefDes	Component
U18	BGA-225
U43	BGA-225
U06	BGA-225
U02	BGA-225
U21	BGA-225
U56	BGA-225
U33	CSP-100
U50	CSP-100
U19	CSP-100
U37	CSP-100
U42	CSP-100
U60	CSP-100
U11	PDIP-20
U51	PDIP-20
U12	TSOP-50
U25	TSOP-50
U24	TSOP-50
U26	TSOP-50



Component Finish/Solder Combinations

SnPb Rework Test Vehicles						
Component	Original Component Finish	Reflow Solder	Wave Solder	New Component Finish	Rework Solder	Board Finish
BGA-225	SAC405	SnPb				Immersion Silver ------- A limited Number of Boards will be Built with ENIG
BGA-225	SnPb	SnPb		SAC405	SnPb	
BGA-225	SnPb	SnPb		SnPb	Flux Only	
CLCC-20	SAC305	SnPb				
CSP-100	SAC105	SnPb				
CSP-100	SnPb	SnPb		SnPb	Flux Only	
CSP-100	SnPb	SnPb		SAC105	SnPb	
PDIP-20	NiPdAu		SnPb			
PDIP-20	Sn		SnPb			
PDIP-20	SnPb		SnPb	Sn	SnPb	
QFN	Matte Sn	SnPb				
TQFP-144	NiPdAu	SnPb				
TQFP-144	SnPb Dip	SnPb				
TSOP-50	Sn	SnPb				
TSOP-50	SnBi	SnPb				
TSOP-50	SnPb	SnPb		SnPb	SnPb	
TSOP-50	SnPb	SnPb		Sn	SnPb	

Profiles used during initial assembly

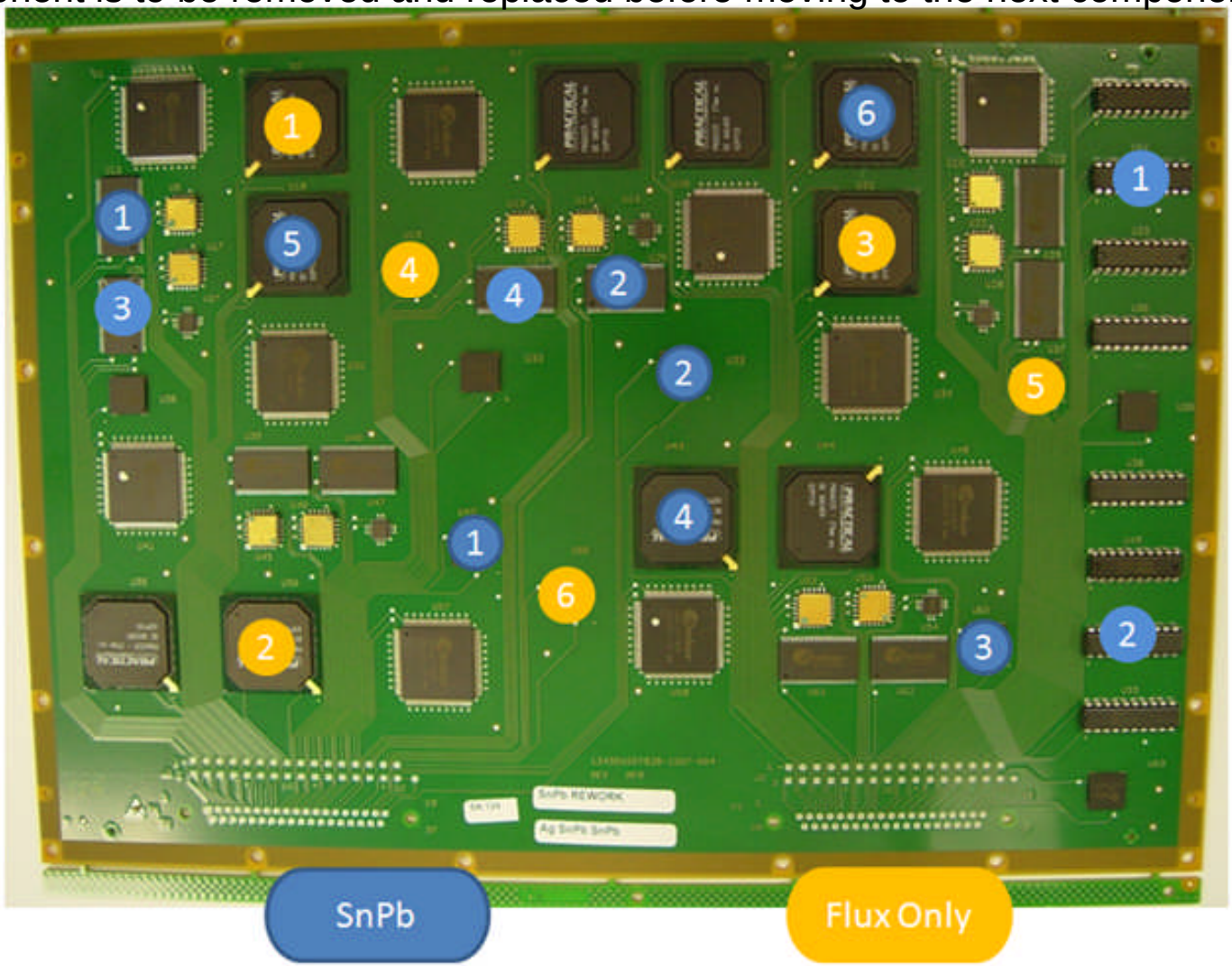
LF profiles used

Reflow Profile = SAC305
Preheat = 60-120 seconds @150-190°C
Peak temperature target = 243°C
Reflow:~20 seconds above 230°C
~30-90 seconds above 220°C

Wave Profile = SN100C
Solder Pot Temperature = 265°C
Preheat Board T = 134°C
Peak Temperature = 157°C
Speed: 90 cm/min

Rework Procedure

- Components being reworked have been grouped by rework solder alloy / material (SnPb, Flux only, SAC305 and SN100C). The location performing the rework can choose what order to rework the solder alloy / material groups, but must use the numbered order below for specific component locations within the solder alloy / material group. When reworking a component, the component is to be removed and replaced before moving to the next component.



Component Finish/Solder Combinations

Lead-Free Rework Test Vehicles						
Component	**Component Finish**	**Reflow Solder**	**Wave Solder**	**New Component Finish**	**Rework Solder**	**Board Finish**
BGA-225	SnPb	SAC305				Immersion Silver
BGA-225	SAC405	SAC305		SAC405	SnPb	
BGA-225	SAC405	SAC305		SAC405	Flux Only	
CLCC-20	SnPb	SAC305				
CSP-100	SnPb	SAC305				
CSP-100	SAC405	SAC305				
CSP-100	SAC105	SAC305		SAC105	Flux Only	
CSP-100	SAC105	SAC305		SAC105	SnPb	
PDIP-20	Sn		SN100C			
PDIP-20	Sn		SN100C	Sn	SN100C	
QFN	SnPb	SAC305				
TQFP-144	NiPdAu	SAC305				
TQFP-144	SAC 305 Dip	SAC305				
TSOP-50	SnBi	SAC305				
TSOP-50	SnPb	SAC305				
TSOP-50	Sn	SAC305		Sn	SnPb	
TSOP-50	SnBi	SAC305		SnBi	SAC305	

Profiles used during initial assembly

Reflow Profile = SAC305
Preheat = 60-120 seconds @150-190°C
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Wave Profile = SN100C
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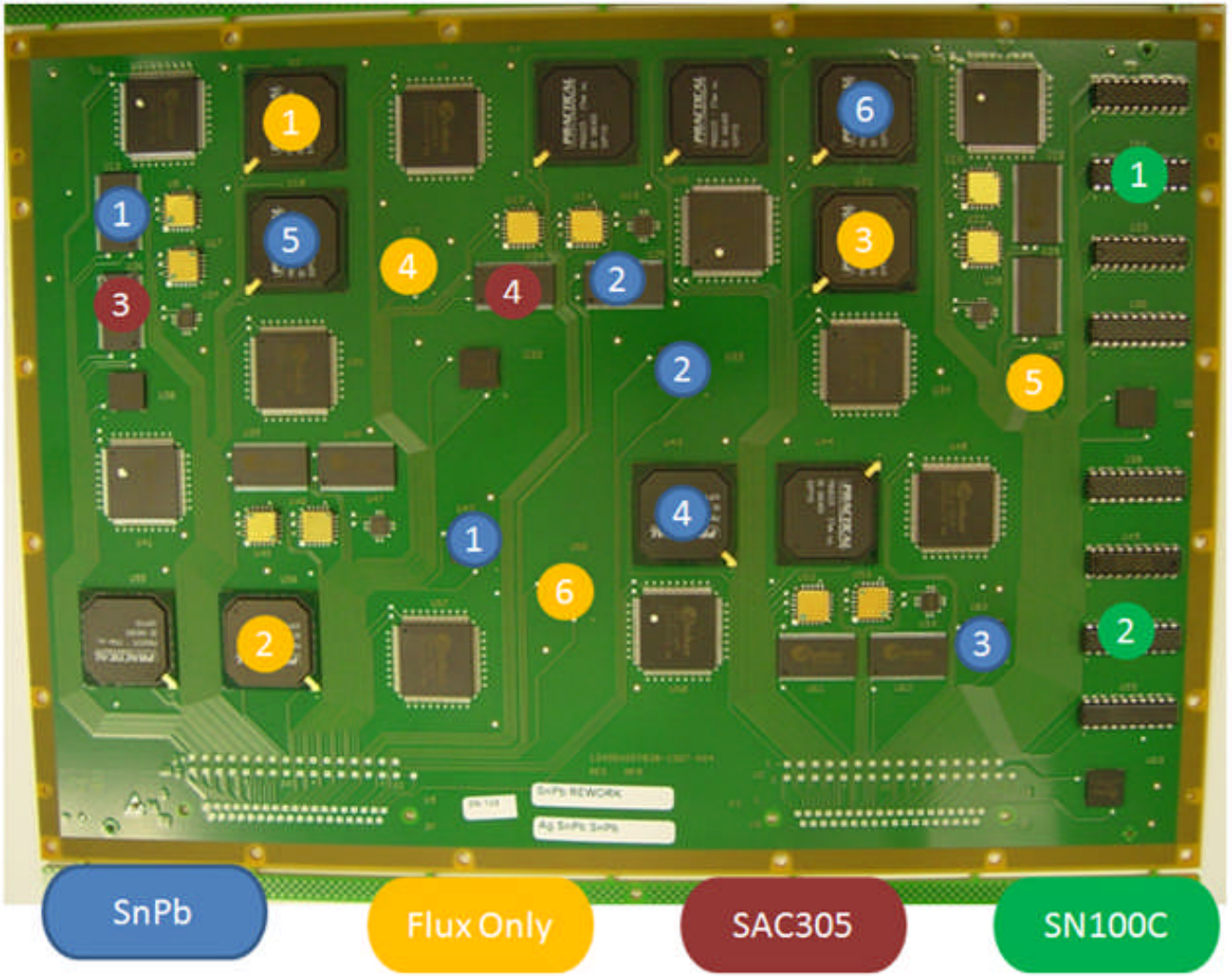
Speed: 90 cm/min

Rework Procedure

- Components being reworked have been grouped by rework solder alloy / material (SnPb, Flux only, SAC305 and SN100C). The location performing the rework can choose what order to rework the solder alloy / material groups, but must use the numbered order below for specific component locations within the solder alloy / material group. When reworking a component, the component is to be removed and replaced before moving to the next component.



NAVSEA Crane Rework Effort

- Built 30 test vehicles (sub-set of the 193 assembled)
  - Test vehicles were built with Lead-Free solder and Lead-Free component finishes only = similar to Manufactured test vehicles for Mechanical Shock, Vibration and Drop Testing
  - Lead-Free alloys, SAC305 and SN100C
  - Rework was done using only SnPb solder
  - Performed multiple pass rework 1 to 2 times on random Pb-free DIP, TQFP-144, TSOP-50, LCC and QFN components
  - Testing
    - Thermal Cycling -55°C to +125°C
    - Vibration Testing
    - Drop Testing

Testing Activities

Specific testing details can be found in the Joint Test Protocol (JTP)
http://www.teerm.nasa.gov/projects/NASA_DODLeadFreeElectronics_Proj2.html

- Thermal Cycle Testing (-20/+80ºC) BOEING
- Combine Environments Testing Raytheon
- Drop Testing CELESTICA
- Thermal Cycle Testing (-55/+125ºC) Rockwell Collins
- Vibration Testing BOEING
- Mechanical Shock Testing BOEING
- Interconnect Stress Test (IST) Interconnect PWB Solutions Inc.
- Copper Dissolution CELESTICA Rockwell Collins

Thermal Cycle Testing (-20/+80°C)

- 5 to 10°C/minute ramp
- 30 minute dwell at 80°C
- 10 minute dwell at -20°C

Test vehicles

- Mfg. SnPb = 5
- Mfg. LF = 5
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5

BOEING

Phase 1 = JCAA/JGPP Lead Free Solder Project Test Results

- 27,135 thermal cycles
  - All of the ceramic leadless chip carriers (CLCC's) and TSOP's failed
  - Most of the BGA's failed (SnPb solder/SnPb balls; SAC solder/SAC balls; SACB solder/SAC balls; and mixed technologies)
  - Most of the TQFP-144's failed

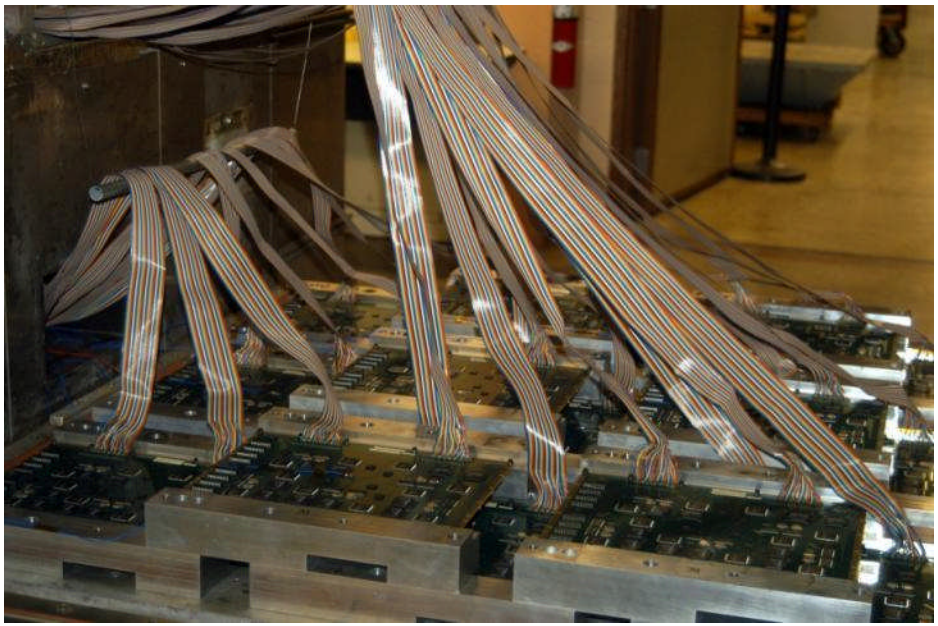
Combine Environments Testing

Thermal Cycle with Vibration

- -55°C to +125°C
- 20°C/minute ramp
- 15 minute dwell at -55°C and +125°C
- Vibration for the duration of the thermal cycle
- 10 g_{rms} pseudo-random vibration initially
- Increase vibration level 5 g_{rms} after every 50 cycles
- 55 g_{rms} maximum

Test vehicles

- Mfg. SnPb = 5
- Mfg. LF = 5
- Mfg. LF (SN100C) = 5
- Mfg. LF (ENIG) = 1
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5

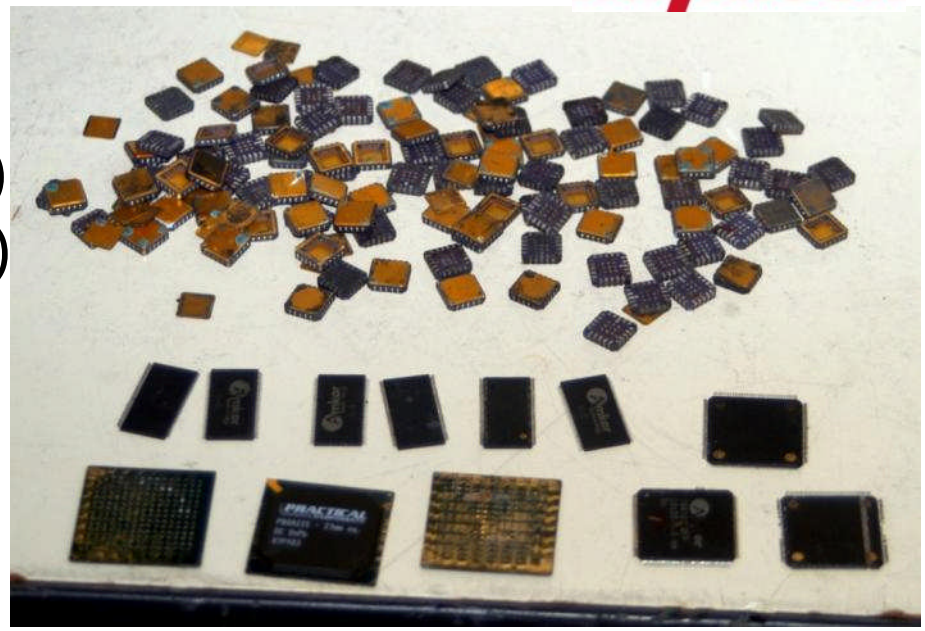


Raytheon

Combine Environments Testing - Status

- “Manufactured” Test Vehicles
- 650 cycles completed on April 1, 2009
  - 121 of 150 BGA’s failed (81%)
  - 139 of 150 CLCC’s failed (93%)
  - 57 of 150 CSP’s failed (38%)
  - 3 of 60 Sn PDIP’s failed (5%)
  - 2 of 60 NiPdAu PDIP’s failed (3%)
  - 20 of 75 QFN’s failed (27%)
    - includes component U15
  - 44 of 150 TQFP’s failed (29%)
  - 36 of 150 TSOP’s failed (24%)

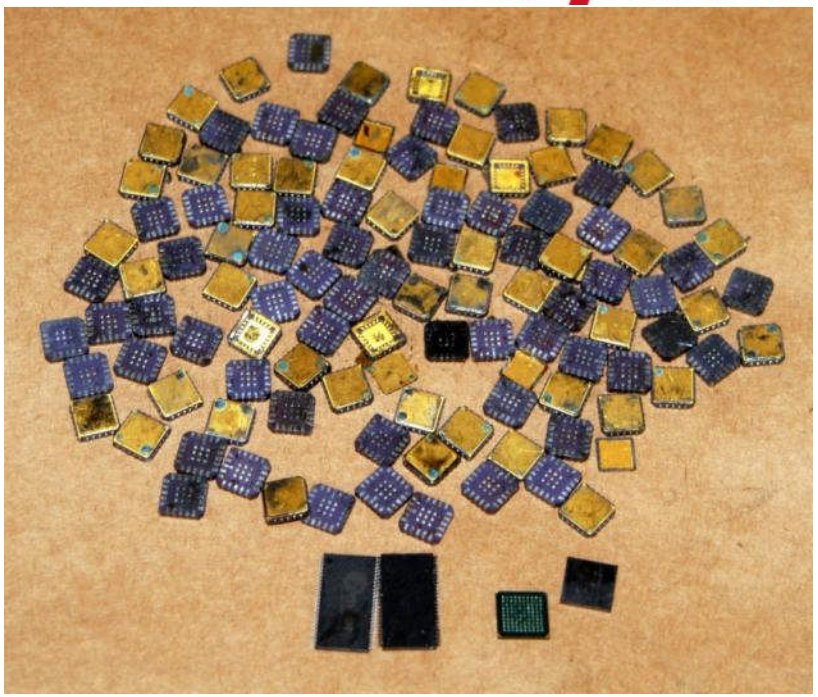
Raytheon



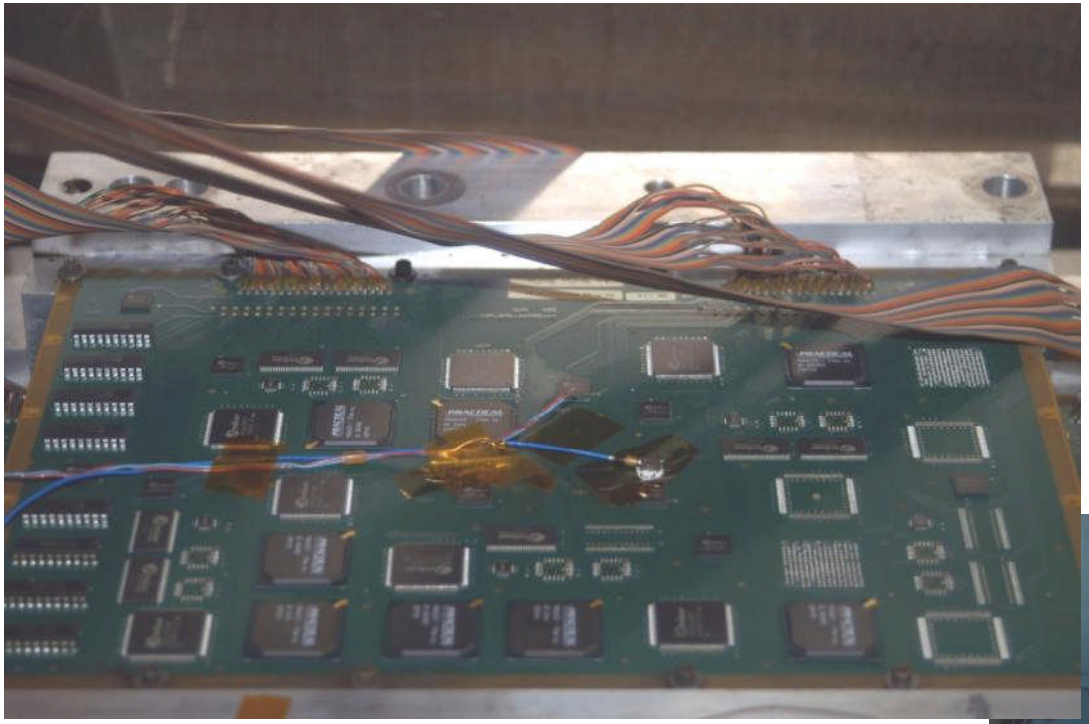
Combine Environments Testing - Status

- "Rework" Test Vehicles
- 650 cycles completed on June 14, 2009
  - –62 of 120 BGA's failed (52%)
  - –115 of 120 CLCC's failed (96%)
  - –34 of 120 CSP's failed (28%)
  - –11 of 96 Sn PDIP's failed (11%)
  - –1 of 60 NiPdAu PDIP's failed (1%)
  - –13 of 60 QFN's failed (22%)
    - –includes component U15
    - –excluding U15 results in 2% fail
  - –18 of 120 TQFP's failed (15%)
  - –57 of 120 TSOP's failed (48%)

Raytheon



Combine Environments Testing
Test Vehicle Wiring



Raytheon

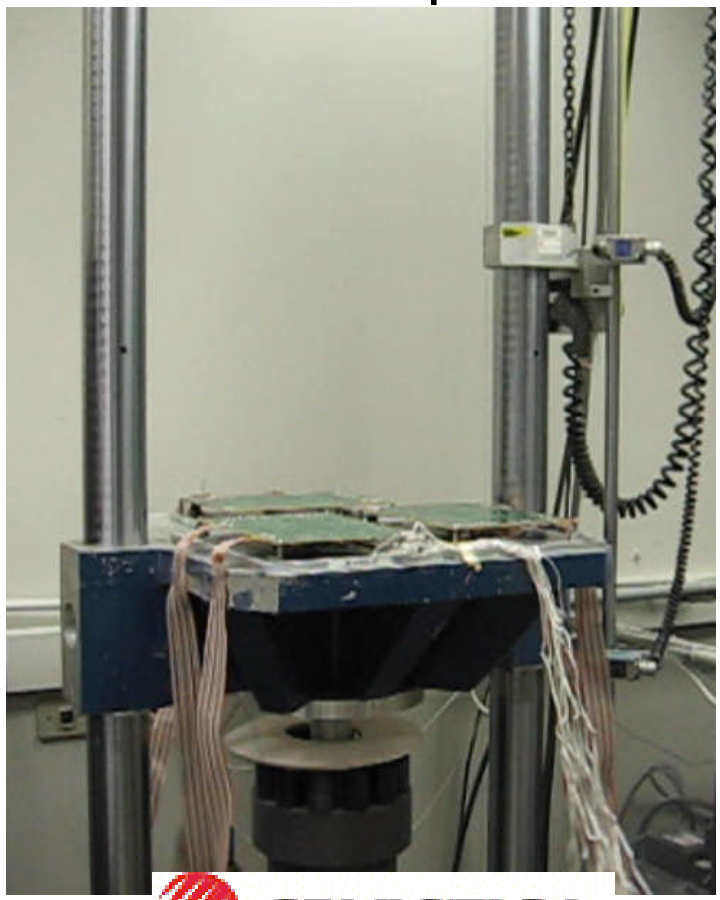
Drop Testing

NASA-DoD Test Vehicles

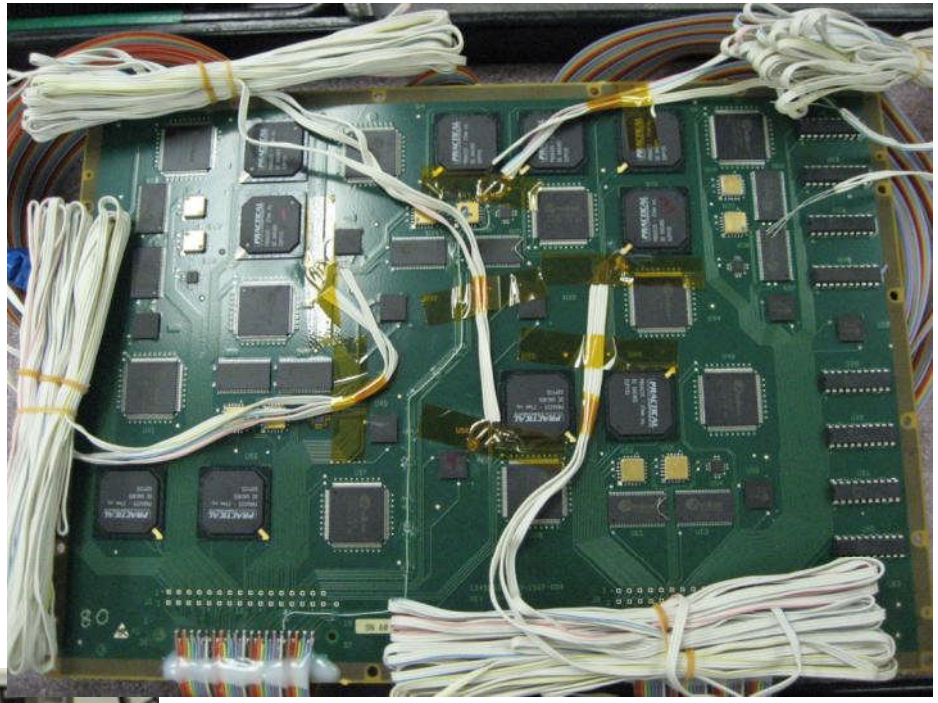
- Shock testing will be conducted in the Z - axis
- 500Gpk input, 2ms pulse duration
- Test vehicles will be dropped until all monitored components fail or 10 drops have been completed

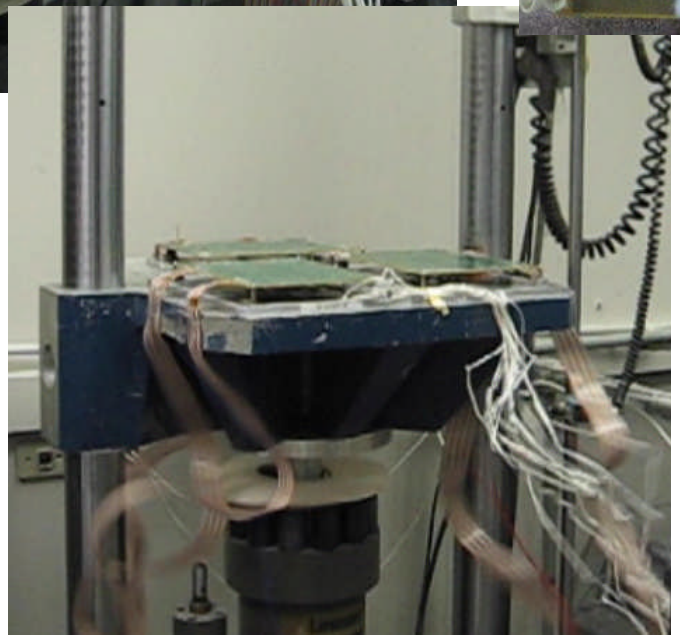
Test vehicles

- Mfg. SnPb = 5
- Mfg. LF = 5
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5



Drop Testing





CELESTICA

NAVSEA Crane Rework Effort
Drop Test Vehicles

- The test vehicles are LF Manufactured
  - LF Reflow (SAC305) / Wave (SN100C)
  - LF profiles
  - All BGA components have SAC405 balls.
- Perform multiple pass SnPb rework 1 to 2 times on random Pb-free DIP, TQFP-144, TSOP-50, LCC and QFN components
- Test vehicles 80, 82, 87 were subjected to 10 drops at 340G and then 10 drops at 500G
- Test vehicles 84, 85, 86; 83, 81, 60 were subjected to 20 drops at 500G only

NAVSEA Crane Rework Effort Drop Test Results

	PBGA 225								
	82	80	87	86	85	84	83	81	60
U18	12	17	15	10	2	6	9	17	0
U56	14	11	13	7	9	8	16	7	14
U55	19	11	19	7	6	3	9	6	15
U2	4	11	14	4	6	4	5	15	17
U4	10	11	6	3	2	4	2	9	6
U43	11	11	6	3	5	6	7	5	8
U21	8	8	10	5	5	3	5	4	5
U44	13	12	10	10	9	7	12	11	16
U5	5	7	5	4	3	2	5	4	4
U6	7	7	5	4	2	2	5	3	3

	CABGA 100								
	82	80	87	86	85	84	83	81	60
U32	0	0	0	0	0	0	0	0	0
U50	0	0	0	0	0	0	0	0	0
U33	0	0	0	0	0	0	0	0	0
U36	0	0	0	0	0	0	0	0	0
U19	0	0	0	0	0	0	0	0	0
U42	0	0	0	0	0	0	0	0	0
U37	0	0	0	0	0	0	0	0	0
U35	0	0	0	0	0	0	0	0	0
U63	0	0	0	0	0	0	0	0	0
U60	0	0	0	0	0	0	0	0	0

Number of Drops To Failure

NAVSEA Crane Rework Effort
Drop Test Results

CLCC 20	82	80	87	86	85	84	83	81	60
U9	0	0	0	0	0	0	0	0	0
U13	0	0	0	0	0	0	0	0	0
U14	0	0	0	0	0	3	0	0	0
U17	0	0	0	0	0	0	0	0	0
U45	0	0	0	0	0	0	0	0	0
U46	0	0	0	0	0	0	0	0	0
U22	0	0	0	0	0	0	0	0	0
U52	0	0	0	0	0	0	0	0	0
U53	0	0	0	0	0	0	0	0	0
U10	0	0	0	0	0	0	0	0	0

0 Rework

QFN 20	82	80	87	86	85	84	83	81	60
U27	0	0	0	0	0	0	0	0	0
U15	0	0	0	18	0	0	0	0	0
U47	0	0	0	0	0	0	0	0	0
U54	0	0	0	0	0	0	0	0	0
U28	0	0	0	0	0	0	0	0	0

2x Rework

PDIP 20	82	80	87	86	85	84	83	81	60
U11	0	0	0	0	0	0	0	0	0
U30	0	0	0	0	0	0	0	0	0
U38	0	0	0	0	0	0	0	0	0
U49	0	0	0	0	0	0	0	0	0
U51	0	0	0	0	0	0	0	0	0
U59	0	0	0	0	0	0	0	0	0
U8	0	0	0	0	17	0	0	0	0
U23	0	0	0	0	0	0	0	0	0

2x Rework

Number of Drops To Failure

NAVSEA Crane Rework Effort
Drop Test Results

TQFP 144	82	80	87	86	85	84	83	81	60
U1	0	0	0	0	0	0	0	0	0
U41	0	0	0	0	0	0	0	0	0
U3	0	0	0	0	0	0	0	0	0
U57	0	0	0	0	7	0	0	0	0
U58	0	0	0	0	0	0	0	0	0
U31	0	0	0	0	0	0	0	0	0
U20	0	0	0	0	0	0	0	0	0
U48	0	0	0	0	0	0	0	0	0
U7	0	0	0	0	0	0	0	0	0
U34	0	0	0	0	0	0	0	0	0

1x Rework

TSOP 50	82	80	87	86	85	84	83	81	60
U26	0	0	0	0	0	0	0	0	0
U39	0	0	0	0	0	0	0	0	0
U40	0	0	0	0	0	0	0	0	0
U25	0	0	0	0	0	0	0	0	0
U12	0	0	0	0	0	0	0	0	0
U24	0	0	0	0	0	0	0	0	0
U61	0	0	0	0	0	0	0	0	0
U16	0	0	0	0	0	0	0	0	0
U62	0	0	0	0	0	0	0	0	0
U29	0	0	0	0	0	0	0	0	0

Number of Drops To Failure

Thermal Cycle Testing (-55/+125°C)

- 5 to 10°C/minute ramp
- 30 minute dwell at 125°C
- 10 minute dwell at -55°C

Test vehicles

- Mfg. SnPb = 5
- Mfg. LF = 5
- Mfg. LF (SN100C) = 5
- Mfg. LF (ENIG) = 1
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5

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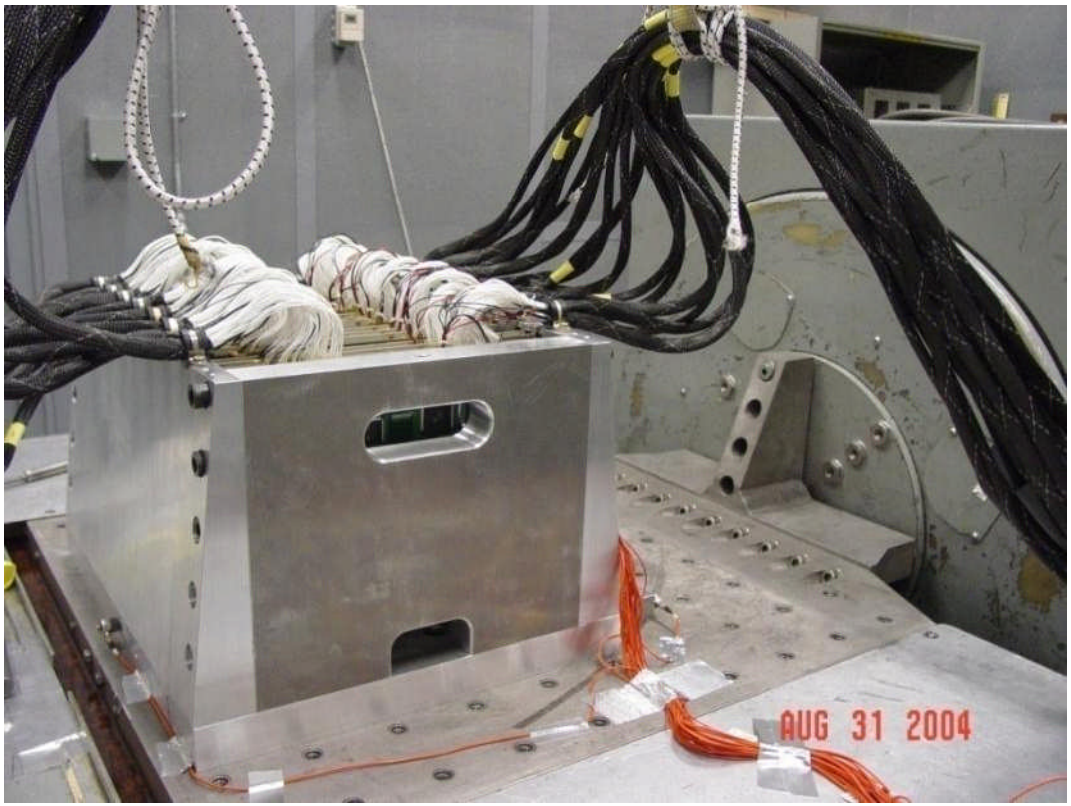
Vibration Testing

- Subject the test vehicles to 8.0 g_{rms} for one hour. Then increase the Z-axis vibration level in 2.0 g_{rms} increments, shaking for one hour per step until the 20.0 g_{rms} level is completed. Then subject the test vehicles to a final one hour of vibration at 28.0 g_{rms}.

Test vehicles

- Mfg. SnPb = 5
- Mfg. LF = 5
- Mfg. LF (SN100C) = 5
- Mfg. LF (ENIG) = 1
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5



BOEING

Mechanical Shock Testing

- Project representatives felt that only testing in the Z-axis was required as this is the only axis which allows significant board bending and subsequent solder joint failures.

Test vehicles

- Mfg. SnPb = 5
- Mfg. LF = 5
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5

The shock transients will be applied perpendicular to the plane of the board and will be increased after every 100 shocks (i.e., a step stress test). Frequency range is 40 to 1000 Hz. SRS damping: 5%			
Test Shock Response Spectra	Amplitude (G's)	Te (msec)	Shocks per Level
Modified Functional Test for Flight Equipment (Level 1)	20	<30	100
Modified Functional Test for Ground Equipment (Level 2)	40	<30	100
Modified Crash Hazard Test for Ground Equipment (Level 3)	75	<30	100
Level 4	100	<30	100
Level 5	200	<30	100
Level 6	300	<30	100
Level 7	500	<30	100
Level 8	700	<30	100

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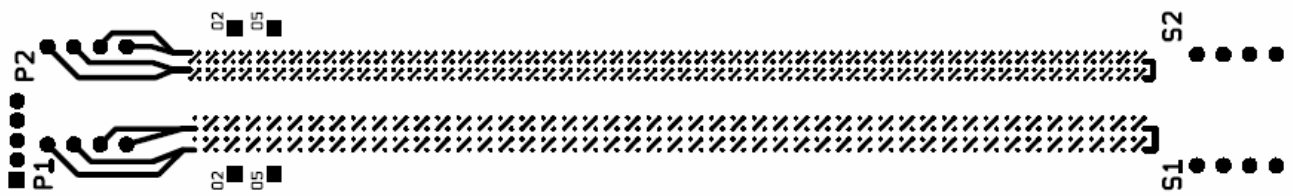
Interconnect Stress Test (IST)

- IST test coupons have two circuits, a sense circuit and a power circuit, to monitor material delamination and crazing. The power circuit heats the coupon and senses damage accumulation on internal interconnections. The sense circuit is a passive circuit that monitors temperature and measures damage accumulation of the interconnect structure, typically a plated through-hole (PTH).

- Accelerates thermal cycling testing by heating a specifically designed test coupon to 150°C (higher temperatures in specific applications in exactly 3 minutes followed by cooling to ambient in approximately two minutes.
- Assembly and rework simulation is achieved by subjecting the coupon to heating to 230°C (260°C for lead-free applications) in three minutes followed by cooling to ambient in approximately 2 minutes.
  - Three thermal cycles simulate assembly
  - Six thermal cycles simulate assembly and rework

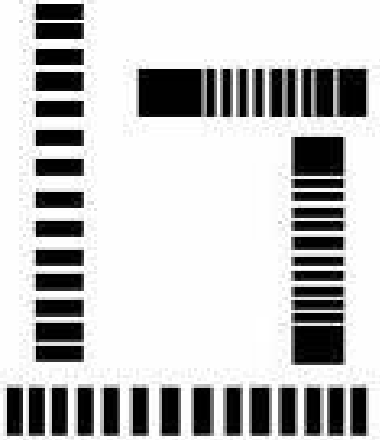


IST Coupon

Copper Dissolution

- Printed Circuit Board (PCB) land and plated through-holes can be eroded or dissolved away in the presence of molten solder rendering the PCB non-functional. Significant dissolution can occur with the use of certain new Sn-rich alloys and is further exacerbated by higher process temperatures.

- Mini-wave soldering versus manual soldering
- Number of component removals: 1X versus 3X
- PDIPS on break off coupon and QFP pad pattern
- Metallographic Analysis:
  - As fabricated copper thickness
  - As assembled copper thickness
- As reworked copper thickness



SMT Copper Dissolution Pattern

Test coupons

- Mfg. SnPb = 5
- Mfg. LF = 5
- Mfg. LF (SN100C) = 5
- Rwk. SnPb = 5
- Rwk. SnPb (ENIG) = 1
- Rwk. LF = 5

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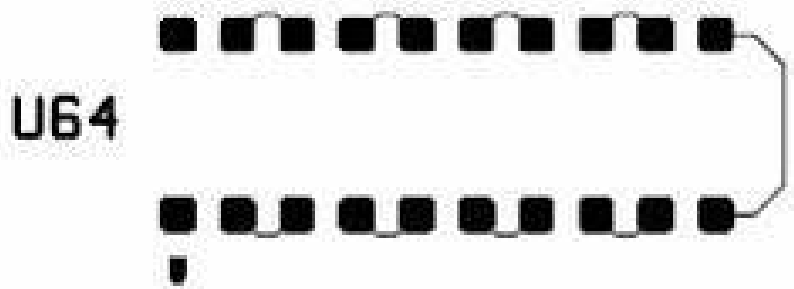
CELESTICA



Plated Through-Hole Copper Dissolution Pattern

Copper Dissolution

- Coupon Exposure Times

	Baseline Plus 5 seconds	Baseline Plus 10 seconds	Baseline Plus 15 seconds
As Manufactured	3	No Sections	No Sections
First Rework	8	No Sections	No Sections
Second Rework	13	23	33
Third Rework	No Samples	No Samples	48

- Yellow boxes indicate cross-sectioned/measured coupons; No Samples indicates no samples will be processed, No Sections indicates that no cross-sectioning will be conducted

Thermal Cycle Test Coupons

- If not consumed as part of Copper Dissolution effort, 5 coupons per alloy, 4 PDIPs per coupon will be processed as Baseline Plus 15 for 48 Total Seconds for each solder alloy and placed in -55°C to +125°C thermal cycle chamber for testing

NASA-DoD Lead-Free Electronics Project

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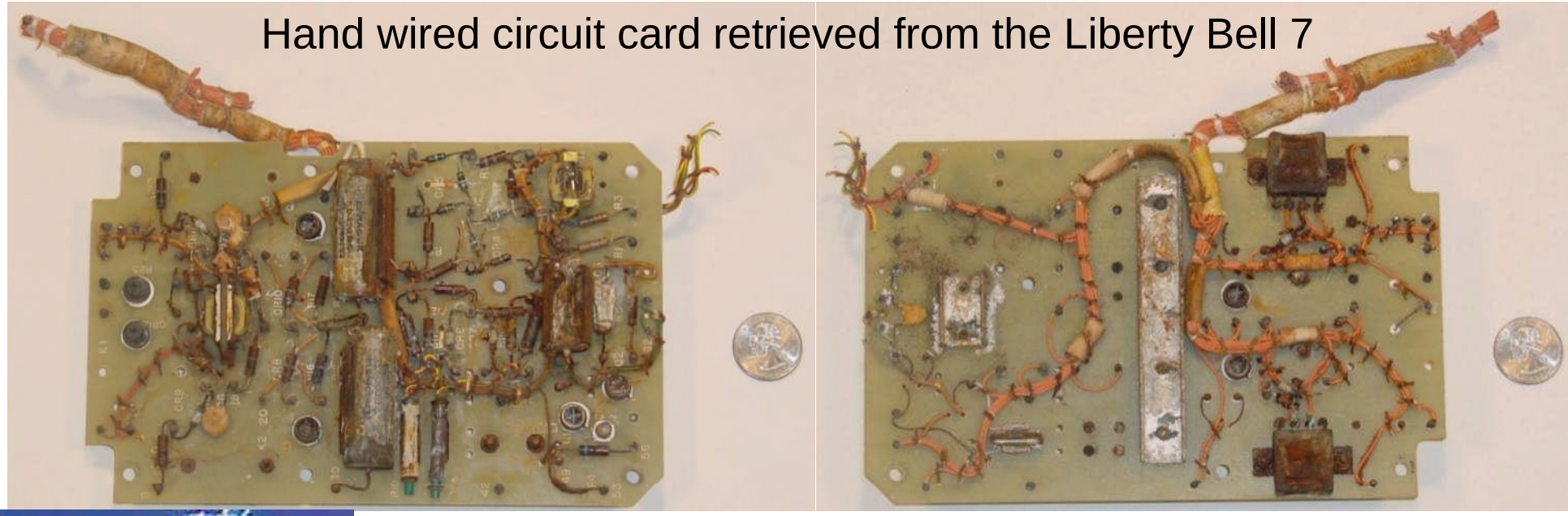
NASA-DoD Lead-Free Electronics Project:
http://www.teerm.nasa.gov/projects/NASA_DODLeadFreeElectronics_Proj2.html

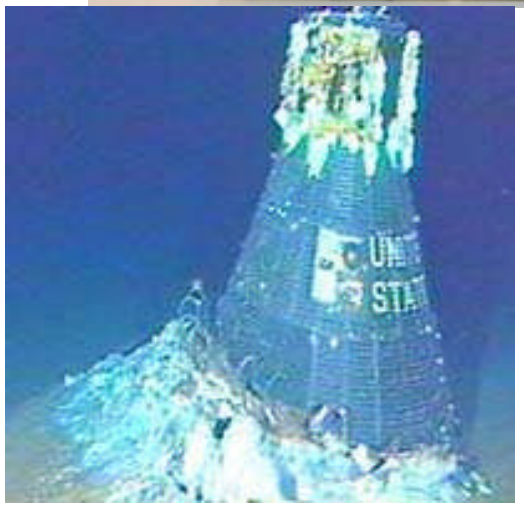
JCAA/JGPP Lead-Free Solder Project
http://www.teerm.nasa.gov/projects/LeadFreeSolderTestingForHighReliability_Proj1.html

Questions

Hand wired circuit card retrieved from the Liberty Bell 7

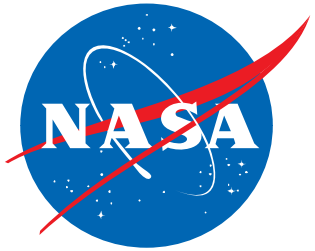


(http://apollotribute.blogspot.com/2005/11/liberty-bell-7-circuit-card.html)



On July 21, 1961 a Mercury/Redstone rocket carried Grissom on a 15-minute trip through space, successfully repeating the feat performed by Alan Shepard two months earlier.

The Liberty Bell 7 was pulled from a depth of 15,000 feet -- 3,000 feet deeper than the Titanic on July 20, 1999


NASA